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ENGINEERING DEPARTMENT

ADVANCED DEVELOPMENT PROGRAM

(NASA CR 55251;)

WATER IMPACT OF THE MERCURY CAPSULE

CORRELATION OF ANALYSIS WITH NASA TESTS

Report No. ADN-02-08-62.1) OTS: Dec~~ember,~~ 1962 13 p refs

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## SUMMARY

13401

The purpose of this note is to compare analytical values of vehicle accelerations and motions with corresponding experimental data from NASA reference (2) for Mercury Space Capsule water landings. The analytical values were obtained by using the procedure from reference (1). Although the comparison is limited to still water, an indication of the validity of the method in obtaining a first approximation to actual water landing effects is evident. Author

## INTRODUCTION

Reference 1, titled, "Water Impact of Manned Spacecraft," is essentially an extension of the NACA approach for rotationally constrained prismatic bodies impacting smooth water. The new features included account for the behavior of a pitching non-prismatic vehicle penetrating rough water. Bottom shapes for which the method was originally intended are roughly similar to seaplane hulls.

The procedure forwarded in reference (1) has been applied to the analyses of 'water landings' of the Apollo Command Module. One of the Apollo design requirements is that it be capable of landing in rough seas with considerable horizontal as well as vertical speed. The predicted results were well within the design requirements.

To establish the applicability of the method, the same analysis procedure was applied to the Mercury Capsule landings, for which test data was available (reference 2). This note contains the results of the correlation.

The numerical procedure utilizes a computer program which employs a predictor corrector integration scheme to solve the equations of motion outlined in reference 1. The program has great flexibility in the printing format allowing close examination of all pertinent parameters. Certain of these parameters, shown as time histories, are correlated with test values of acceleration, immersion, depth and pitch angle.

Figures 1 and 2 show the full scale capsule dimensions and the body reference system used.

## DISCUSSION

The mathematical model employed in the procedure is that shown in Figure 3. The spherical bottom of the Mercury Capsule is represented by a series of wedges each with a 10° deadrise angle. Because of the constant deadrise, the chine heights are adjusted to retain a circular planform representative of the sphere-cone intersection. The wedge thicknesses are halved in the areas near the points of initial impact in order to decrease the effect of individual wedge immersions.

### A - Acceleration Curves

It will be noted when considering Figures (4, 5) that although the peak values are satisfactory, the acceleration onset rate lags the experimental results. This characteristic is inherent in the idealization used since a fixed deadrise angle independent of immersion depth is used. This causes the actual model, which is nearly flat during the initial stages of impact, to be approximated by a wedge with a 10° deadrise angle. The fact that the peak value in Figure (5) does not correspond to the NASA curve can also be attributed to this feature.

The steps in the curves are caused by the immersion of a wedge of finite longitudinal length (rise), and the immersion of a chine (drop). This effect can be modified by subdivision of wedges to decrease the immersing length.

B - Immersion and Pitch Curves

With respect to the immersion and pitch curves, it is found that for the initial stages $0 < t < 2$ seconds, there is fair correlation with test results within the limits of the mathematical solution. The limitations of the procedure are contained in the fact that no hydrodynamic damping forces are included in the formulation. This causes the amplitudes of immersion to exceed actual test results and precludes the generation of viscous type forces. The effect, however, is not as pronounced initially as it is at $t > 2$ seconds since impact effects predominate.

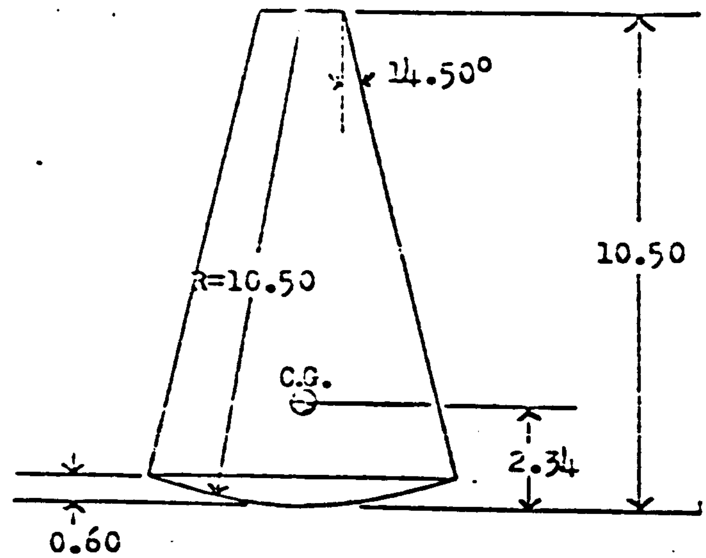
## CONCLUSION

Correlation between analytic and test values indicate that the method is applicable as a first approximation for design purposes. When used in this way, the value of the procedure is evident. Any improvements in the technique to increase accuracy must be accompanied by considerable theoretical advances either in the field of wedge immersion or immersion of other shapes.

## REFERENCES


1. Mueller, W.H.; Malakoff, J.L.; "Water Impact of Manned Spacecraft," Grumman Aircraft Engineering Corporation, ARS Journal, December 1961.

2. McGehee, John R.; Hathaway, M.E.; Vaughan, V.L., Jr.; "Water Landing Characteristics of a Re-entry Capsule," Langley Research Center, Langley Field, Virginia, NASA Memo 5-23-59L.




Note: The weight of the capsule is 2150 pounds and its mass rotational inertia is 540 slug-ft$^2$.

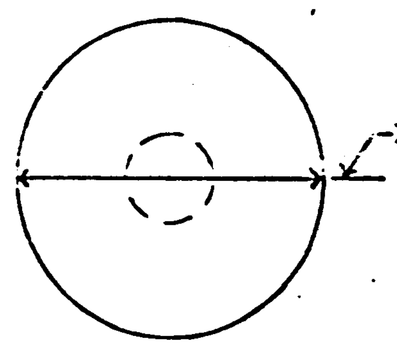



Figure 1.- Capsule configuration. (All dimensions are in feet, full scale.)

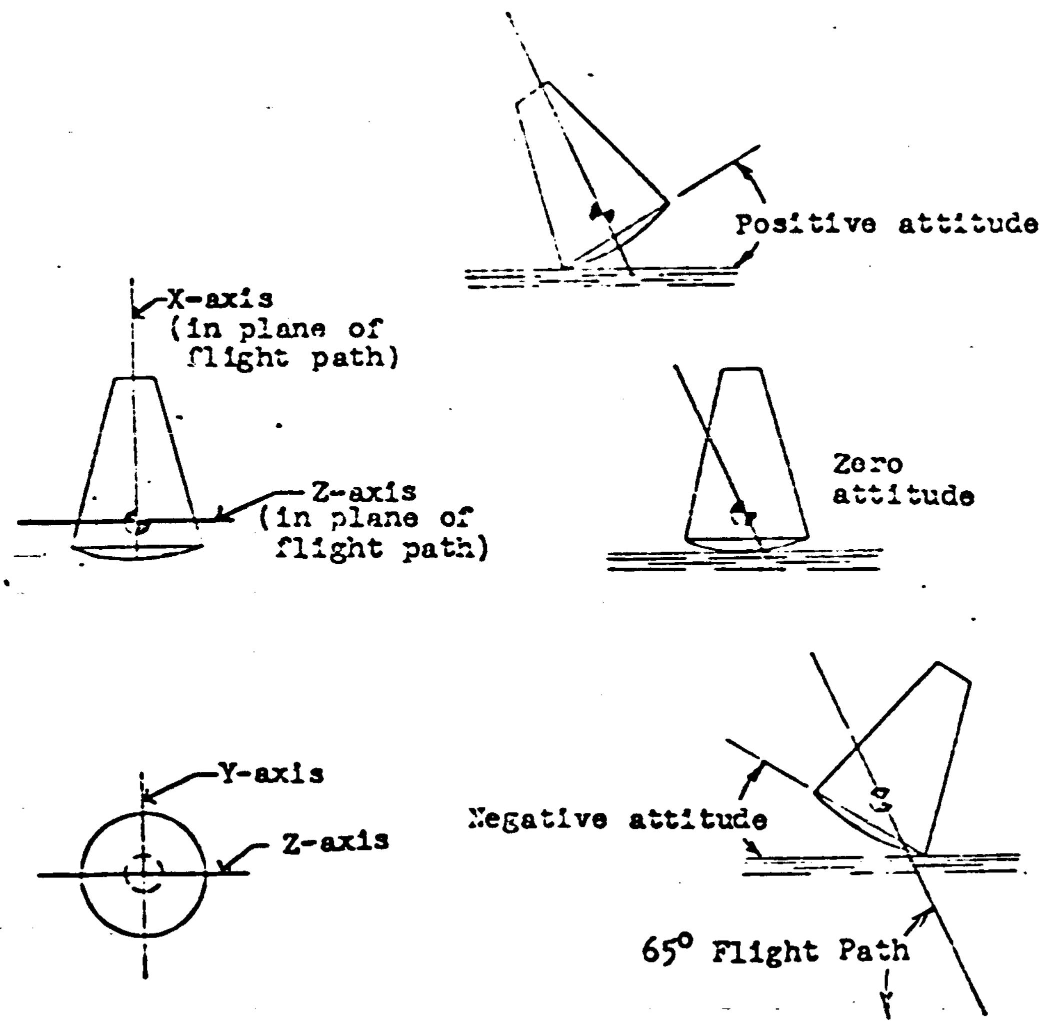
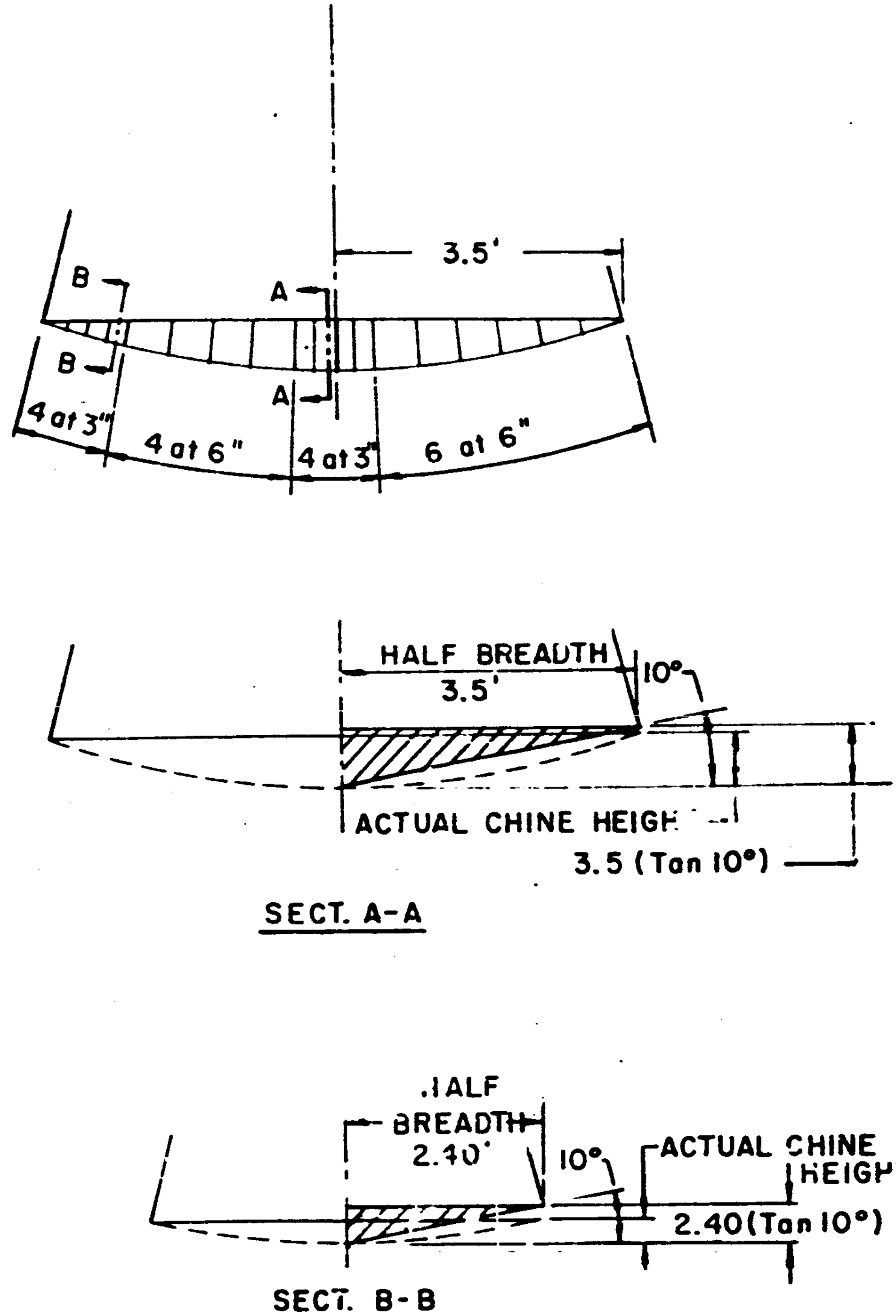



Figure 2.- Sketches identifying axes, flight paths, and impact attitudes.




WEDGE CONFIGURATION OF CAPSULE BOTTOM

FIG. 3

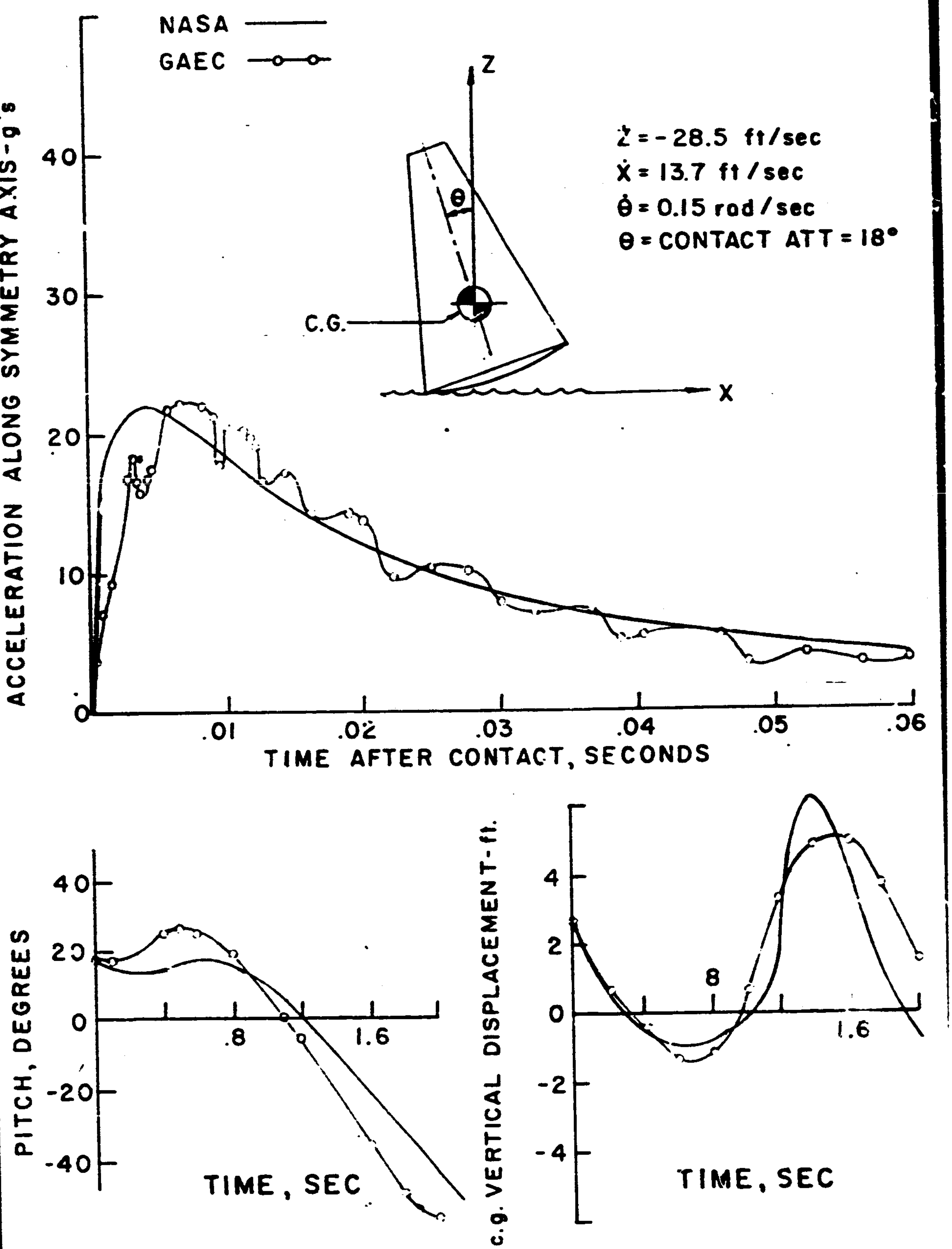
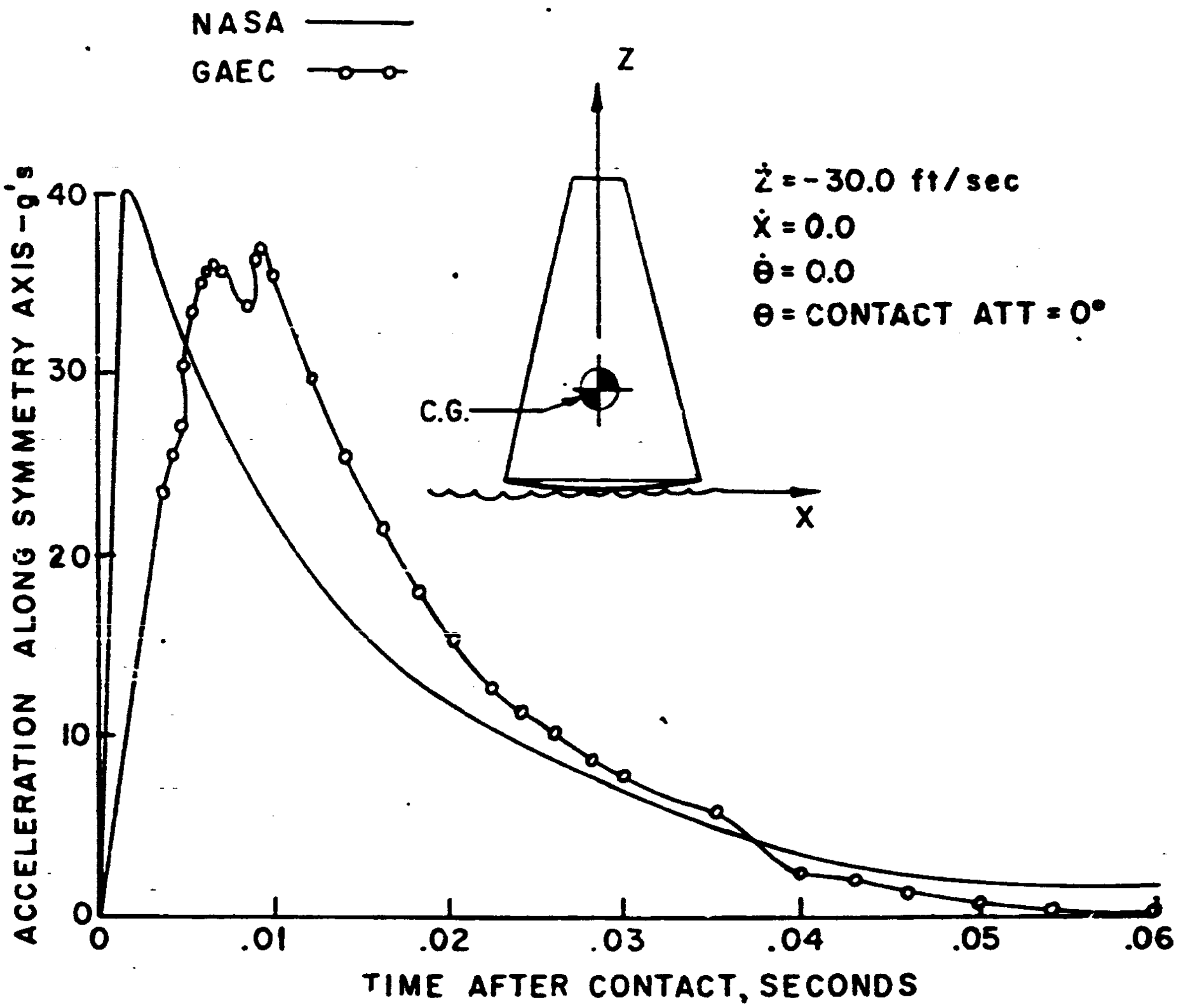

NASA
GAEC
Z
$\dot{Z}$ = -28.5 ft/sec
$\dot{X}$ = 13.7 ft/sec
$\dot{\theta}$ = 0.15 rad/sec
θ = CONTACT ATT = 18°
θ
C.G.
X
ACCELERATION ALONG SYMMETRY AXIS-g's
40
30
20
10
0
.01
.02
.03
.04
.05
.06
TIME AFTER CONTACT, SECONDS
PITCH, DEGREES
40
20
0
-20
-40
.8
1.6
TIME, SEC
c.g. VERTICAL DISPLACEMENT-ft.
4
2
0
-2
-4
8
1.6
TIME, SEC

FIG. 4




NO PITCH

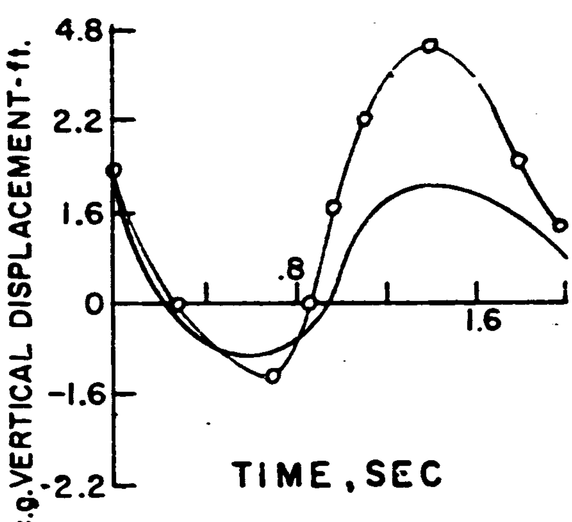



FIG. 5

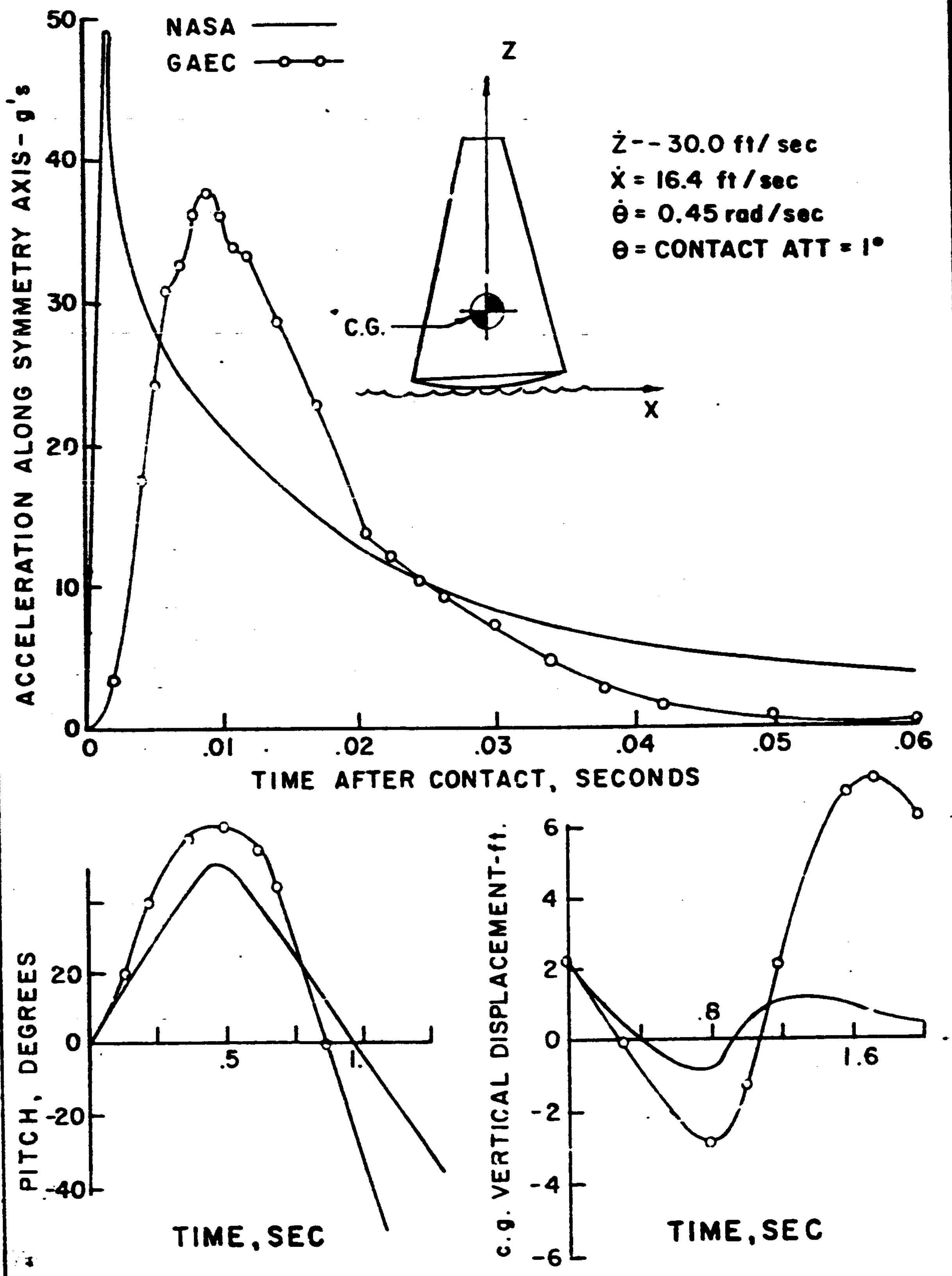

NASA
GAEC
ACCELERATION ALONG SYMMETRY AXIS - g's
TIME AFTER CONTACT, SECONDS
0
.01
.02
.03
.04
.05
.06
10
20
30
40
50
Z
X
C.G.
Ż = -30.0 ft/sec
Ẋ = 16.4 ft/sec
θ̇ = 0.45 rad/sec
θ = CONTACT ATT = 1°
PITCH, DEGREES
TIME, SEC
.5
1.
-40
-20
20
c.g. VERTICAL DISPLACEMENT-ft.
TIME, SEC
.8
1.6
6
4
2
-2
-4
-6

FIG. 6